

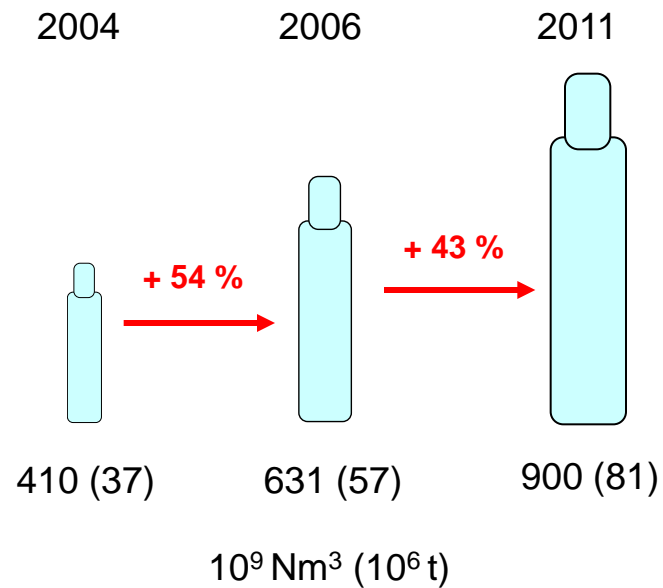
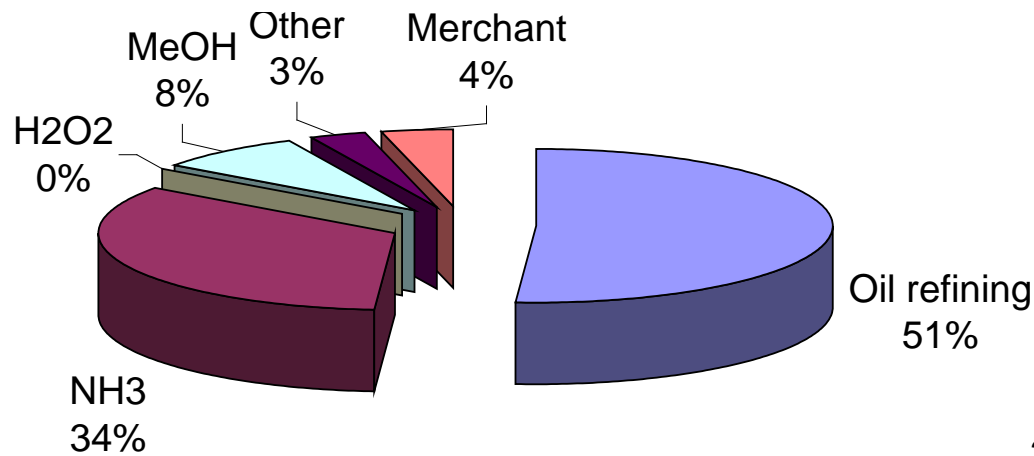


*Technologies for free-CO₂ H₂
production
Michel Junker
ALPHEA Hydrogène*

Contents

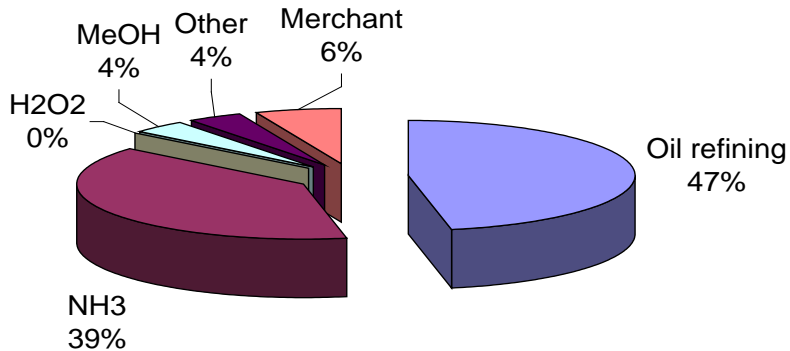
- ❑ Today's hydrogen market
- ❑ Hydrogen production : state of the art
- ❑ CO₂-Free H₂ production

Hydrogen market : World (2006)

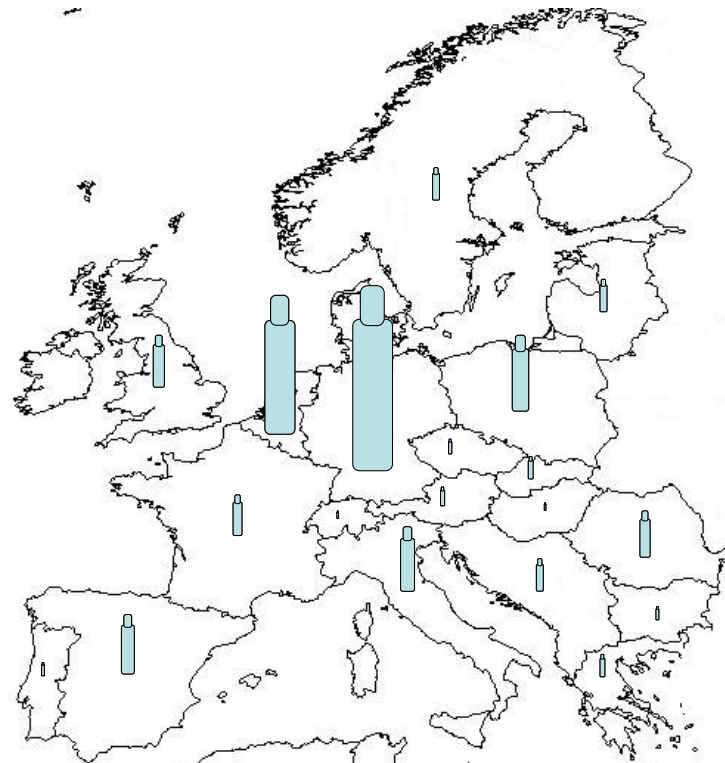
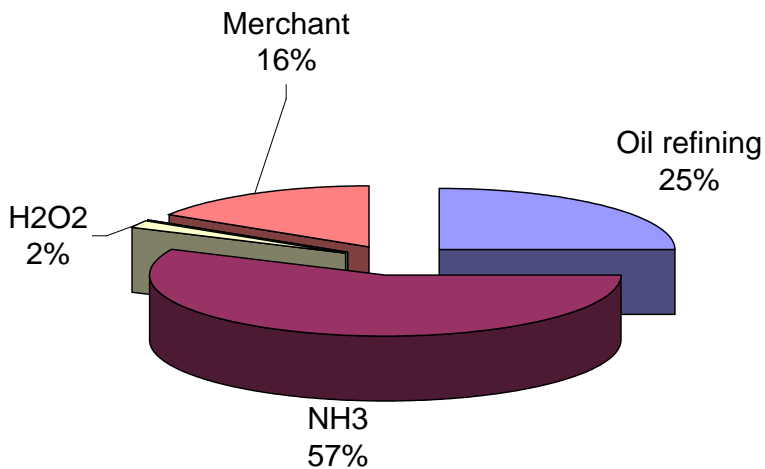


Hydrogen market : Europe & France(2006)

Europe : $92,8 \cdot 10^9 \text{ Nm}^3$

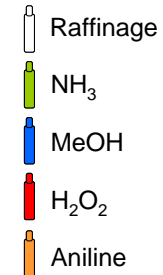


France : $5,57 \cdot 10^9 \text{ Nm}^3$

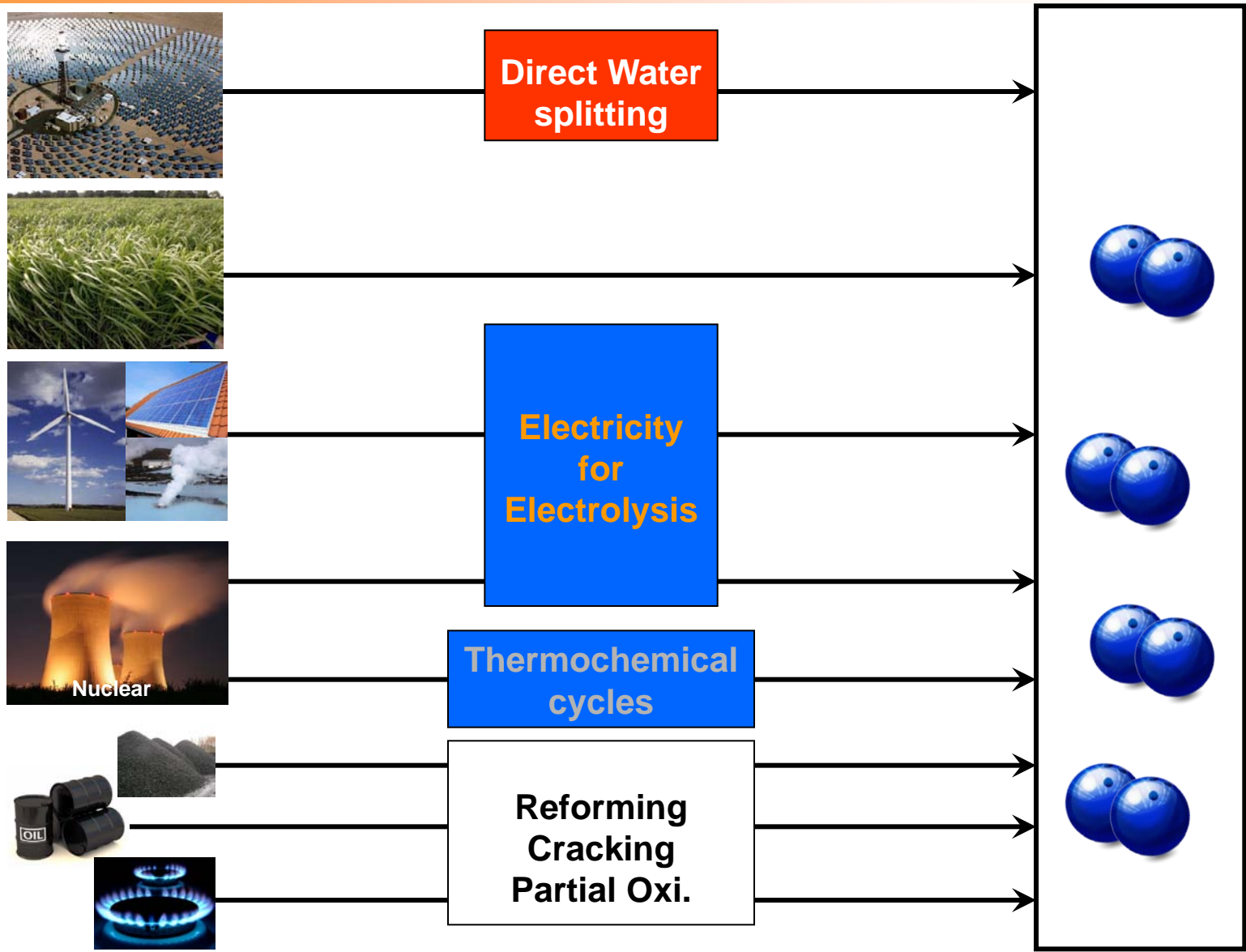


D	34000
B-NL-L	26000
PL	14000
I	12000
E	11000
GB	9700
ROM	8600
F	7800
P. Baltes	5900
Balkan	5720
Scand.	5600
GR	4400
SK	4100
A	3600
CZ	2900
BG	2600
P	2500
CH	1200
H	960

x 1000 Nm³/j



Hydrogen production



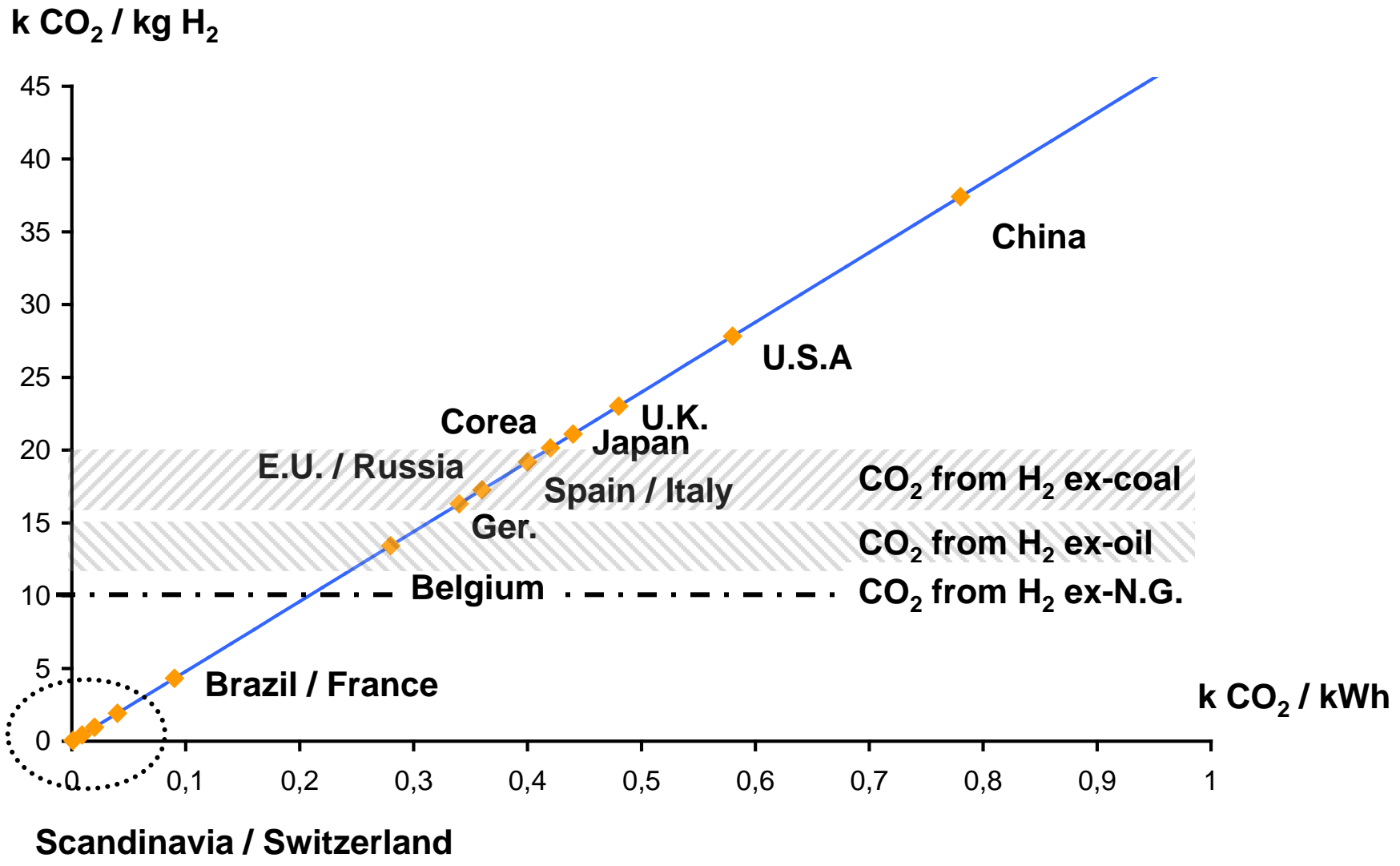
Hydrogen production

Commercial processes

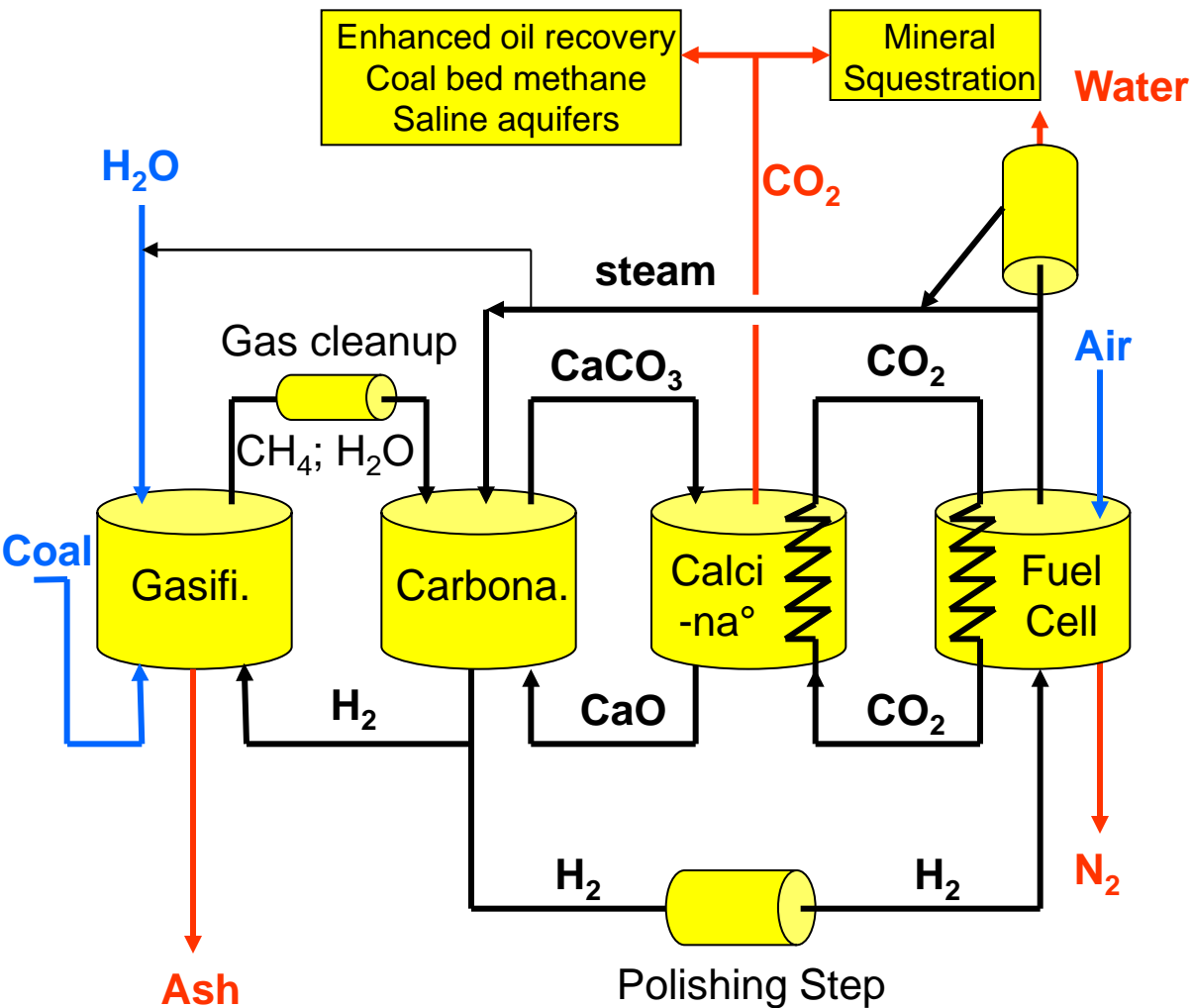
Energy	Yield	Carbone dioxide		Hydrogen		
		Emission	Treatment Overcost	Plant scale	Purity	Cost
Coal	~ 60	16 - 19	2.2 - 3	90 - 350	95 – 99.5	9 -15
Natural Gas	60 – 70	10	1 – 2.4	80 – 250	99.9	5 – 7
Oil	50 - 90	12 - 15	n.c.	60 - 120	99.5	8 - 12
Water electrolysis	~ 60	=f(CO ₂ / kWh)	/	29 (*)	> 99.9	= f(\$ / kWh)
	%	kg / kg H ₂	\$ / GJ H ₂	k Nm ³ / h	%	\$ / GJ

(*) capacity of the world largest plant

Hydrogen production : CO₂ from water electrolysis

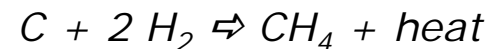


ZEC (Zero Emission Coal) process

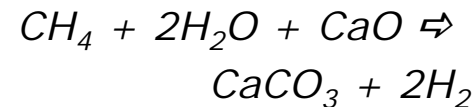


Process

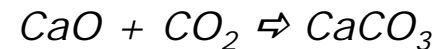
Hydro-Gasification



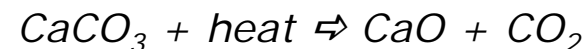
H₂ production, CO₂ removal



Reforming energy from



Pure CO₂ regeneration

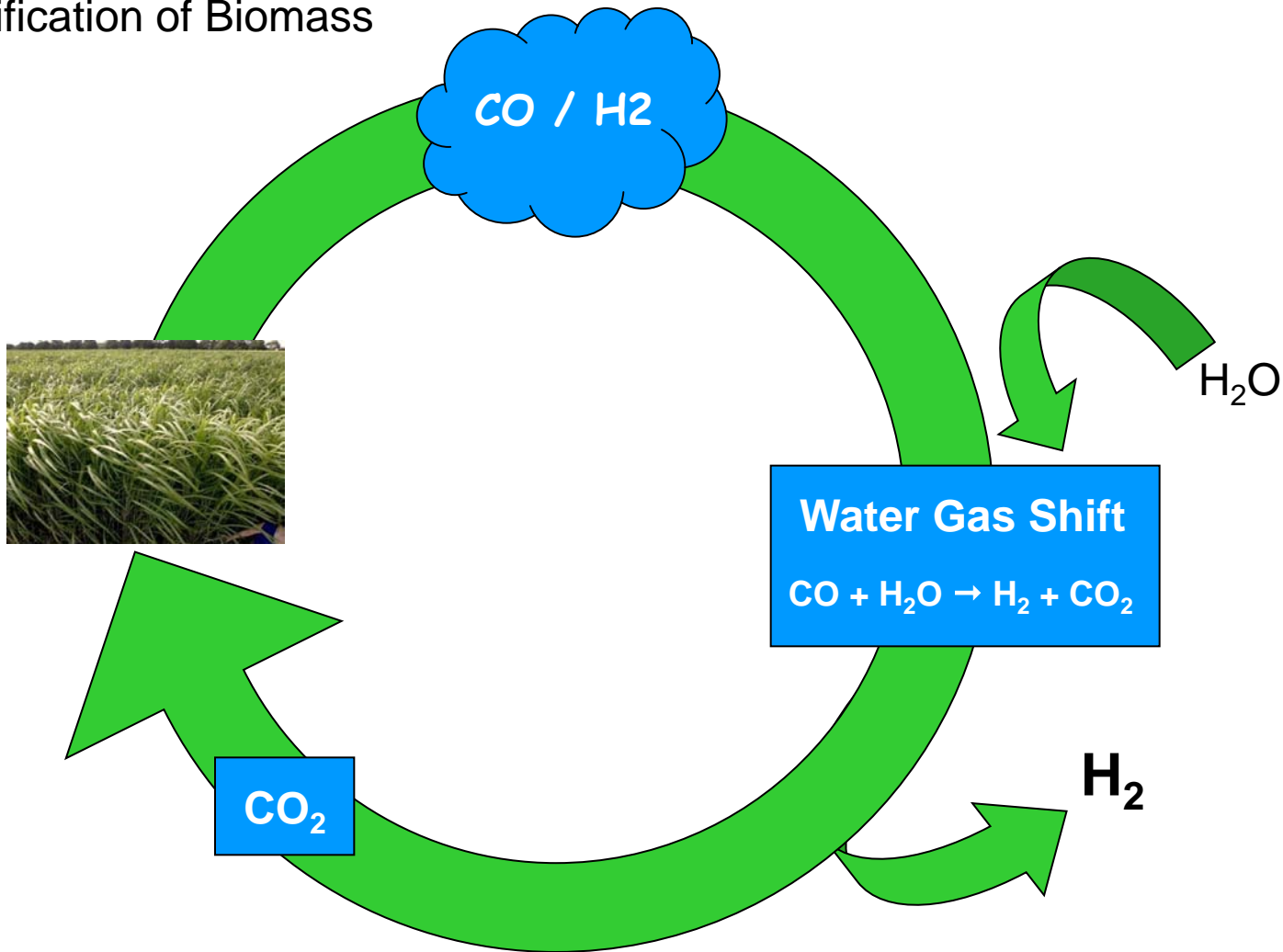


Hydrogen production from renewable

- ❑ Coupling Windturbines, PV panels, geothermal energy with electrolyzers
- ❑ Gasification of Biomass
- ❑ Photo or thermal water splitting
- ❑ « Bio-fuel » 3rd generation

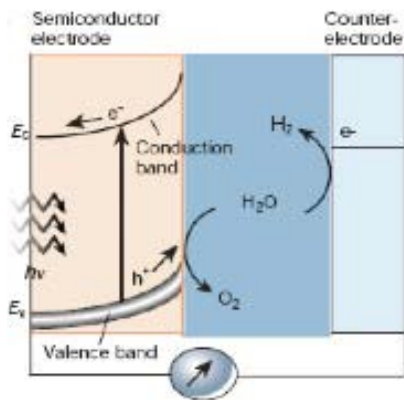
Hydrogen production from renewable

Gasification of Biomass

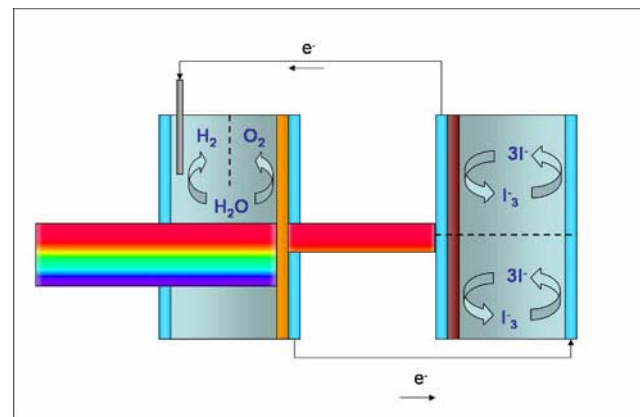


Hydrogen production from renewable

Photo water splitting

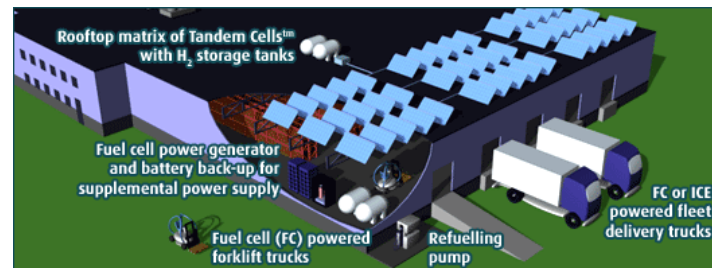


Grätzel cell



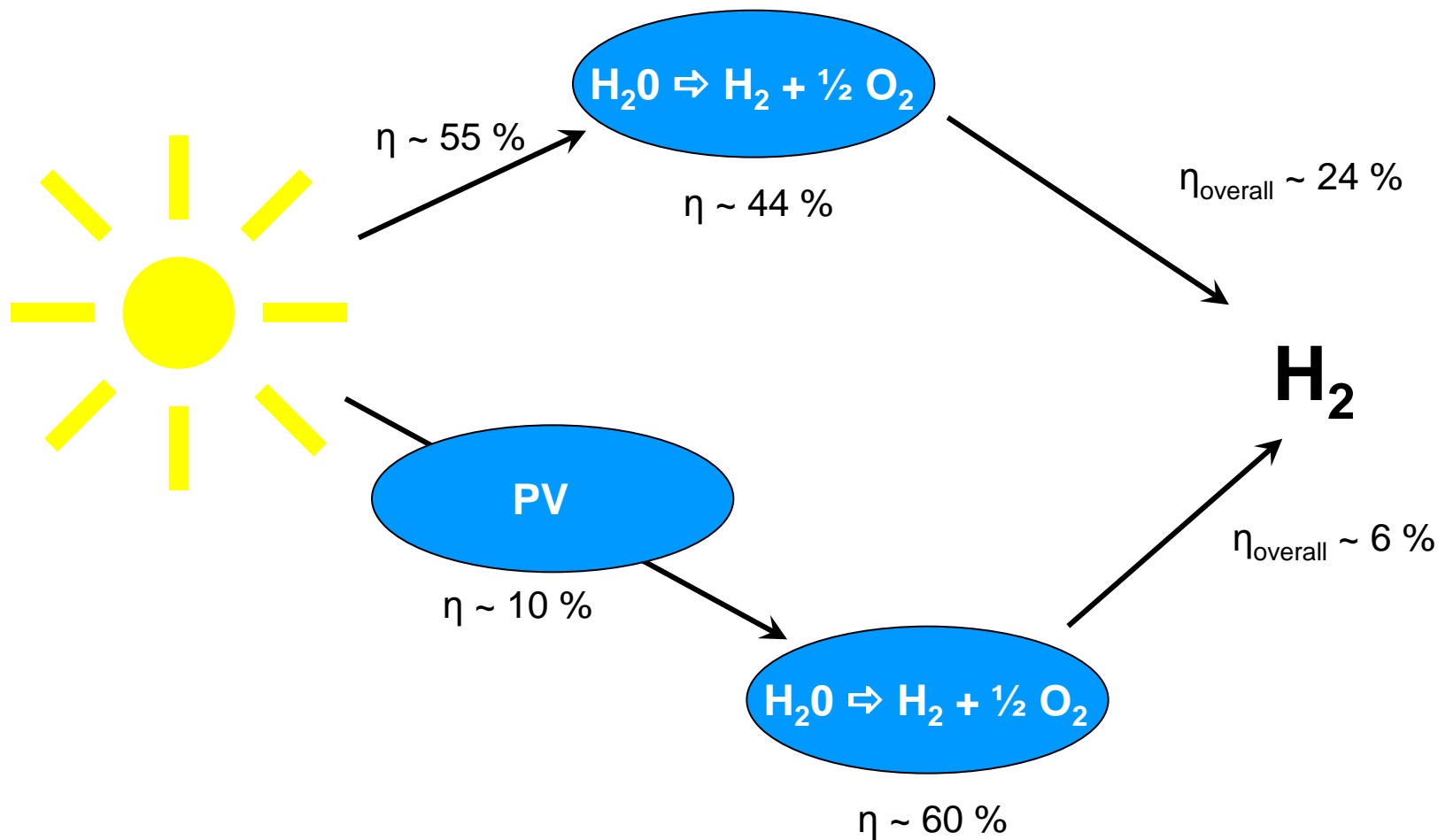
Photoelectrochemical cell

Applications :



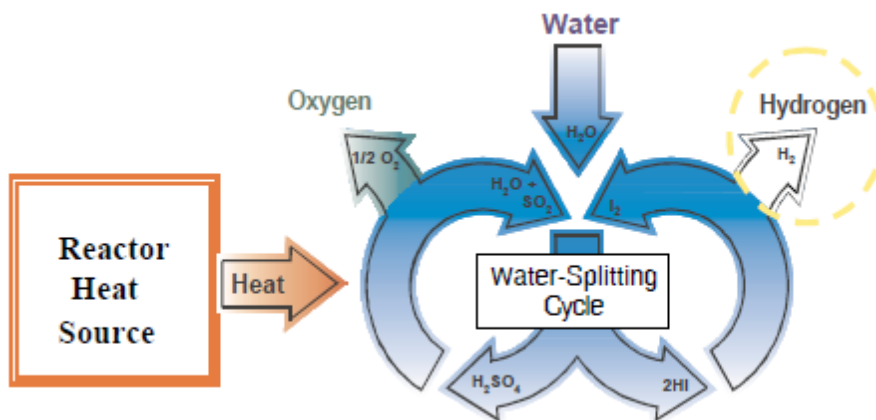
Hydrogen production from renewable

Solar thermal water splitting



Hydrogen production from nuclear

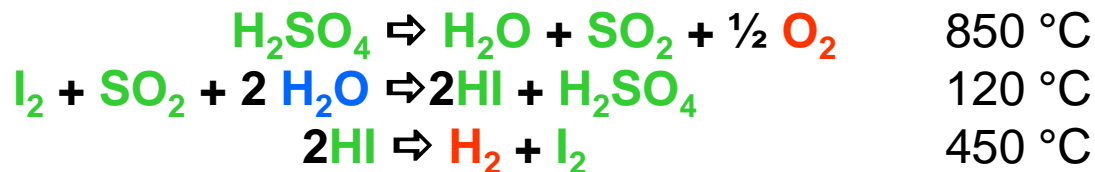
Thermochemical cycle



Input

Output

Recycled



Hydrogen production from nuclear

Thermochemical cycle

- ❑ Leaders in R & D
 - General Atomics Inc
 - Japan Atomic Energy Research Institute
 - C.E.A

- ❑ $\eta \sim 50 \%$ can be reached

- ❑ H₂ cost : 10 \$ / GJ or 1,22 \$ / kg

Main processes

- ❑ Water biophotolysis by algae or cyanobacteria
- ❑ Decomposition of organic waste by photosynthetic bacteria
- ❑ Water gas shift by bacteria
- ❑ Fermentation by bacteria (⇒ hydrogen production only)